

**THE MAINTENANCE OF KEY PECKING BY
STIMULUS-CONTINGENT AND
RESPONSE-INDEPENDENT FOOD PRESENTATION**

ELKAN GAMZU AND BARRY SCHWARTZ

HOFFMANN-LA ROCHE INC. AND SWARTHMORE COLLEGE

Three naive pigeons were exposed to a series of two-component multiple schedules of response-independent food presentation. The component schedules were sometimes identical (non-differential procedures) and sometimes different (differential procedures). High rates of key pecking were maintained in all the differential procedures, and pecking decreased substantially in non-differential procedures, even when the frequency of food presentation in non-differential procedures was higher than in differential procedures. It is suggested that the high rates of key pecking were maintained not by adventitious response-reinforcer contingencies, but by differential contingencies between the stimulus (keylight) and food. The role of such contingencies in the phenomenon of behavioral contrast is discussed.

If a pigeon that has been trained to peck on an illuminated key to produce food is then exposed to a procedure in which food delivery occurs without regard to its behavior (response-independent food presentation), the response is nevertheless maintained at non-zero rates (Appel and Hiss, 1962; Edwards, West, and Jackson, 1968; Herrnstein, 1966; Herrnstein and Morse, 1957; Lachter, 1971; Neuringer, 1970; Zeiler, 1968). Similar findings have been reported with rats and bar pressing (Edwards, *et al.*, 1968; Lattal and Mazey, 1971; Rescorla and Skucy, 1969; Skinner, 1938, pp. 163-166). This phenomenon has typically been explained as a corollary of the effects of response-dependent reinforcement (*e.g.*, Herrnstein, 1966). Food presentation reinforces (increases in frequency) whatever behavior precedes it. Thus, any behavior in which a food-deprived organism is engaged at the time of food delivery is more likely to occur subsequently. If the next food presentation is soon forthcoming, there is an increased probability that the behavior in question will

again precede it. In this fashion, response-independent food presentation can maintain a given class of behavior. However, since an explicit dependency between the behavior and the food is absent, the organism at times will obtain food with an appreciable delay since the last occurrence of the behavior in question, or immediately after engaging in any of a number of different behaviors. Thus, behavior other than the one being measured will also be strengthened, which is consistent with the observation that responding is maintained at a lower rate by response-independent than by response-dependent food presentation.

However, an alternative account of the effectiveness of response-independent food presentation in maintaining key pecking in the pigeon has been offered by Staddon and Simmelhag (1971). They argued that the presence of food in a situation, combined with a pigeon's state of food deprivation, will induce the pigeon to peck in that situation. Moreover, they reported that while pigeons engaged in a wide variety of behaviors in the time intervals between response-independent food presentations, in the time just before delivery of the food, all pigeons were pecking. They further suggested that the rate of pecking is no lower when food delivery is response-independent than when it is response-dependent: the difference in pecking between the two situations is that the locus of the peck is more variable when food delivery is response-

¹This research was supported by NSF Grant G14055 to David R. Williams, principal investigator, and was conducted at the University of Pennsylvania. The second author was a Natural Science Foundation pre-Doctoral Fellow. The authors wish to thank David R. Williams for his guidance through all phases of the work, and Thomas Allaway, Joseph Bernheim, Jay McClelland, and Alan Silberberg for the helpful comments on earlier versions of this manuscript. Reprints may be obtained from Elkan Gamzu, Hoffmann-La Roche Inc., Nutley, New Jersey 07110.

independent. What an explicit dependency between pecking and food presentation does, according to Staddon and Simmelhag, is decrease the variability of peck location, and not increase the rate of pecking. The recorded increase in pecking that experimenters invariably observe when an explicit dependency is introduced is due to the fact that only pecks directed at a particular location—the response key—are being counted.

An implication of the Staddon and Simmelhag account is that food presentation, coupled with an appropriate state of deprivation, directly enhances certain classes of (biologically appropriate) behavior and that a response-reinforcer dependency merely selects behavior from among those classes. The major difference between the accounts of the effectiveness of response-independent food presentation proposed by Herrnstein (1966) and by Staddon and Simmelhag (1971) is that Herrnstein views food presentation as blindly strengthening whatever behavior happens to precede it, while Staddon and Simmelhag view food presentation as directly determining what behavior will precede it.

Given that direct, or non-contingent effects of food presentation² enhance pecking, the question arises as to what variables channel pecking toward a particular locus, the response key. Staddon and Simmelhag suggested that explicit response-reinforcer dependencies serve this function. However, another view emphasizing stimulus-reinforcer contingencies similar to those of classical conditioning has been suggested in a number of studies by Gamzu and Williams (1971; see also, Gamzu, 1971). In a discrete-trial procedure, the illumination of a pecking key was correlated with a response-independent, or variable-time (VT) schedule of food presentations, while the absence of the key was sometimes correlated with the same VT schedule and sometimes correlated with the absence of food. When food presentations occurred only in the presence of the illuminated key (differential condition), naive pigeons developed and maintained high rates of key pecking. When food

presentations also occurred in the absence of the illuminated key (non-differential condition), key pecking decreased.

The rates of responding observed by Gamzu and Williams (1967) were substantially higher than those obtained in other experiments on response-independent food presentation (*e.g.*, Neuringer, 1970; Zeiler, 1968), despite the fact that the pigeons had never been exposed to an explicit response-reinforcer dependency. Gamzu and Williams suggested that this elevated response rate was due to the response-key's role as an informative signal for the presentation of food.

The experiments of Gamzu and Williams differ from those cited above in that their procedures consisted of discrete trials. The present experiment attempted to extend these findings to a more typical free-operant situation. Naive pigeons were exposed to series of multiple schedules of response-independent food presentation. A multiple schedule is one in which the component schedules are in force successively, each correlated with a different external stimulus. In some cases, the component schedules were identical, (*e.g.*, *mult* VT 33-sec VI 33-sec) so that the stimuli on the key were not effective signals for food presentation because the delivery of food was equiprobable in the presence of both stimuli. In other cases, the component schedules differed (*e.g.*, *mult* VT 33-sec EXT) so that the stimuli on the keys were effective signals, in that each stimulus was associated with a different conditional probability of food presentation. In this way, the importance of the stimulus-food contingency to the maintenance of key pecking by response-independent food presentation was assessed.

METHOD

Subjects

Three, experimentally naive Silver King pigeons were maintained at 80% of their free-feeding weight.

Apparatus

The center key of a three-key Lehigh Valley pigeon chamber (Model No. LV 1519C) could be illuminated with either red or green light; the other two keys were covered with black masking tape. The feeder was located below the center key, and the houselight was located

²"Non-contingent effects of food presentation" should not be confused with "effects of non-contingent food presentation". Non-contingent effects of food presentation may be present even when food presentation is contingent on responding, and hence, also has contingent effects.

above the key. A deflector directed the light from the houselight toward the ceiling of the chamber. Automatic scheduling and recording equipment were contained in another room.

Procedure

The pigeons were first trained to eat from the feeder. They were then exposed, with no prior key-peck training, to the series of multiple schedules of food presentation listed in Table 1. Each of the component schedules in force in a given multiple schedule was correlated with a different color, either red or green. (The color associated with component Schedule 1 for a given multiple schedule is indicated for each pigeon by the letter R or G following the number of sessions. Schedule 2 was associated with the alternate color.) The schedules of food delivery were of two types: schedules in which food was presented, independently of responding, separated by variable intervals of time (VT 33-sec and VT 100-sec schedules with intervals selected from geometric frequency distributions); and schedules in which food was never presented (EXT). It is important to note that at no time in the course of the experiment was the delivery of food dependent on the occurrence of a key peck.

Each daily session consisted of eighty, 27-sec components, alternating between green and red illumination of the center key. A food presentation consisted of 4-sec access to mixed grain, during which time a light in the feeder was illuminated and the houselight and key-light were extinguished.

RESULTS

The six procedures examined in the present experiment may be divided into two classes: differential procedures (I, III, and V),

in which the schedules of food presentation correlated with the two stimuli differed, and non-differential procedures (II, IV, and VI), in which the schedules of food presentation correlated with the two stimuli were identical. Mean response rates for each pigeon averaged across the last three sessions of each procedure are given in Figure 1a. In calculating response rates, food presentation time was subtracted from total time where applicable, thus allowing for direct comparison of response rates in all procedures. Each of the pigeons began to peck the key in Procedure I (with no training), and substantial rates of pecking were maintained throughout the procedure. Pecking was maintained at a higher rate on the VT schedule than on the EXT schedule, though substantial responding occurred in EXT as well. When the procedure was changed to *mult* VT 33-sec VT 33-sec (Procedure II), responding in both schedules decreased dramatically (to zero in the case of Pigeon 2853). This decrease in responding occurred despite the fact that the frequency of food presentation on one of the schedules was unchanged, while the frequency of food presentation on the other schedule was increased (in fact, the number of food presentations per session in Procedure II was twice that in Procedure I).

Procedure III was a replication of Procedure I, except that the stimuli correlated with VT and EXT schedules were reversed. In effect, the difference between Procedures II and III is that the frequency of food presentation in one of the schedules was decreased from 1.8 per minute to zero. Nevertheless, response rate in that schedule increased for all three pigeons, as did response rate in the other schedule, which was unchanged. When the schedules were again non-differential (Procedure IV), responding in both schedules again decreased markedly.

Table 1
Summary of Procedures

Procedure	Component Schedule 1	Component Schedule 2	P2853 # Sessions	P21 # Sessions	P21 # Sessions
I	VT 33-sec	EXT	15 (R)	15 (R)	15 (G)
II	VT 33	VT 33-sec	18 (R)	24 (R)	33 (G)
III	EXT	VT 33	30 (R)	24 (R)	15 (G)
IV	VT 33	VT 33	29 (G)	39 (G)	39 (G)
V	VT 33	VT 100	21 (G)	21 (G)	24 (G)
VI	VT 100	VT 100	45 (G)	48 (G)	15 (G)

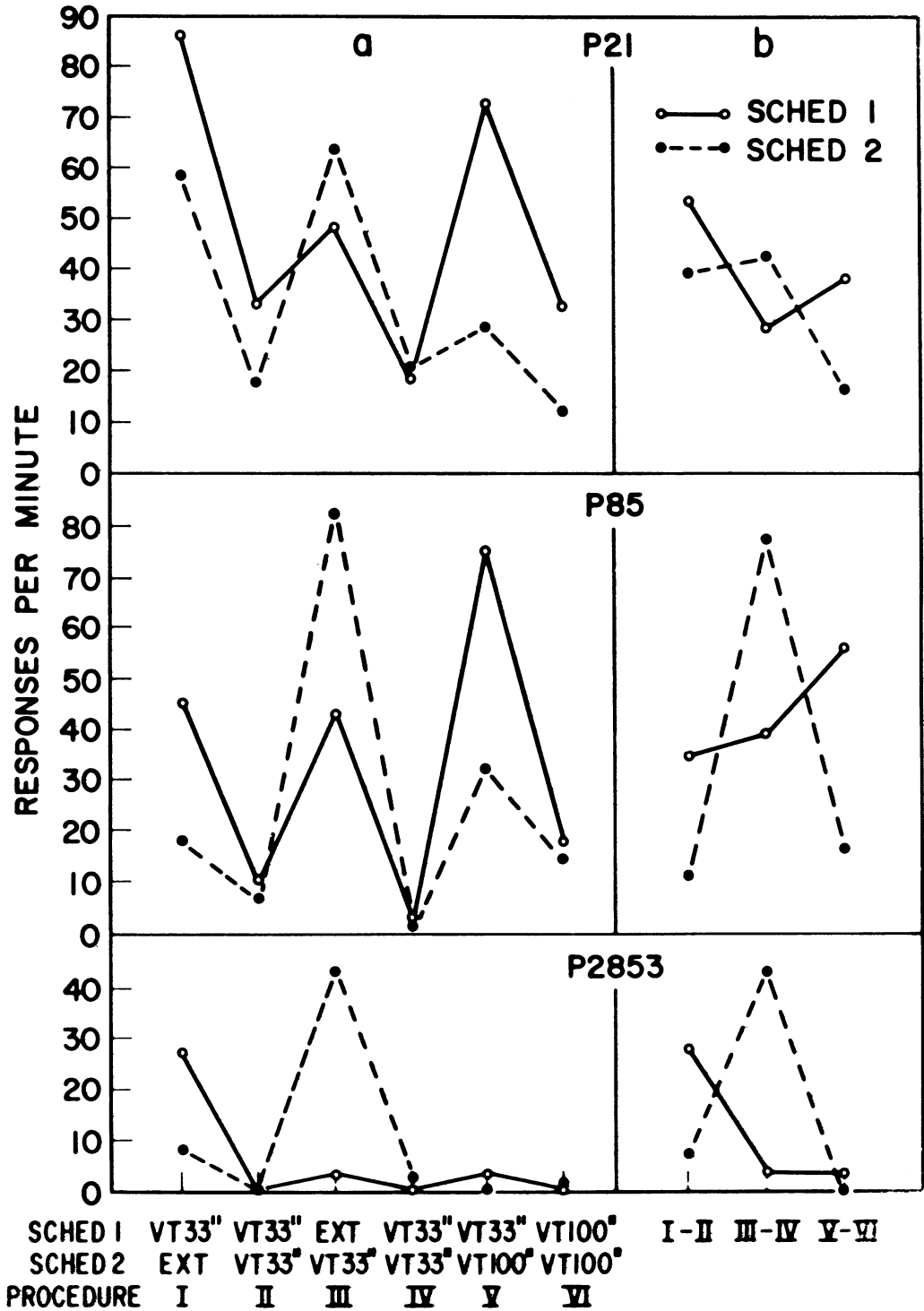


Fig. 1. (a) Responses per minute in each of the component schedules averaged across the last three sessions of each procedure, for each of the pigeons. The component schedules are identified on abscissa. (b) Responses per minute from the same sessions as in (a). Procedure II response rates are subtracted from Procedure I response rates, IV and III, and VI from V. See text for further detail.

In Procedure V, the possibility was examined that the effectiveness of the differential procedure lay in the contrast between some food and no food. In Procedure V, food was presented in both schedules, but with different frequencies (1.8 per minute and 0.6 per minute). For Pigeons 85 and 21, the *mult* VT 33-sec VT 100-sec maintained substantially more responding than the *mult* VT 33-sec VT 33-sec, even in the schedule in which the frequency of food presentation had been decreased. The return to the non-differential procedure (VI) differed from Procedures II and IV in that it represented a decrease rather than an increase in overall frequency of food presentation. The effect of this procedure was the same as Procedure II and IV, however; responding decreased substantially.

To assess the effect of the differential procedure in maintaining responding relative to the non-differential procedure, response rates maintained on the non-differential procedures were subtracted from response rates maintained on the immediately preceding differential procedures (I-II, III-IV, V-VI). The re-

sulting response rates are plotted in Figure 1b. In all cases, response rate was higher on a differential procedure than on its neighboring non-differential procedure.

Figure 2 presents a picture of the session-to-session changes in responding across all the procedures for Pigeon 85. Each data point represents the mean response rate across a three-session block. Though pecking was slow to develop initially, subsequent changes in procedure produced rapid, steady changes in response rate.

DISCUSSION

The present data support and extend the data obtained by Gamzu and Williams (1971) as to the importance of the response key as a signalling stimulus in the maintenance of responding by response-independent food presentation. Only in the differential procedures, in which the two stimuli were correlated with different schedules of food presentation, thus making the stimuli effective signals, was responding maintained. In addition, the *mult*

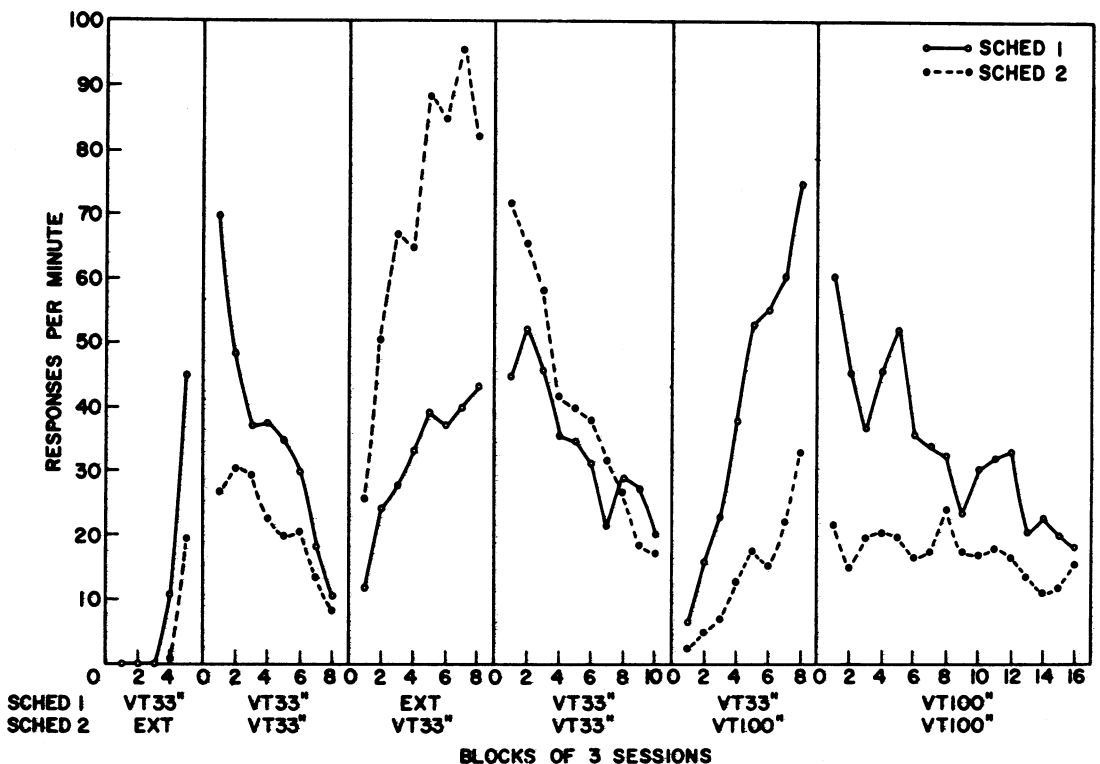


Fig. 2. Responses per minute in each of the component schedules for Pigeon 85, averaged across blocks of three sessions. Component schedules are identified on the abscissa.

VT-EXT procedure represents an extension of the class of procedures by which key pecking in the pigeon can be automatically shaped (Brown and Jenkins, 1968).

An account of the maintenance of responding by response-independent food presentation in terms of the principles established in the study of response-dependent food presentation (Herrnstein, 1966) cannot explain the present data. If key pecking were originally established in Procedure I via adventitious reinforcement, then one might expect the increased overall frequency of food presentation in Procedure II to increase responding, or maintain responding unchanged, but certainly not to decrease it. Moreover, the fact that all three pigeons engaged in key pecking, rather than some other behavior, makes it unlikely that the effect of food presentation is blindly to strengthen whatever behavior precedes it.

Rather, an account of the effects of response-independent food presentation along the lines suggested by Staddon and Simmelhag (1971) is compatible with the present results. The delivery of food to a hungry pigeon engenders pecking. That the response key becomes the target of the peck is explained by the fact that the key stimulus is a differential signal for food presentation. When the effectiveness of the key stimulus as a signal is eliminated (non-differential procedure), key pecking, though not necessarily pecking, declines.

However, the continued responding at high rates in component schedules associated with lower frequencies of food presentation (*i.e.*, EXT and VT 100-sec in Procedures I, III, and V) raises the question of what precisely are the conditions under which a stimulus will be pecked at by the naive pigeon. One possibility is that the key stimulus merely has to be informative with respect to food, *i.e.*, be unambiguously associated with a schedule of food delivery different from that which obtains in the absence of the stimulus. This predicts that pigeons should peck at a key that is clearly associated with the absence of food. This is clearly not the case. Brown and Jenkins (1968) reported very little key pecking in a reverse-pairing auto-shaping procedure, and Gamzu (1971) did not observe pecking on a white key when food was delivered only in the intertrial interval. Another pos-

sibility is that the key stimulus merely has to signal food presentations, *i.e.*, food is delivered during the key-stimulus presentation irrespective of whether it is available in the absence of the stimulus and at what frequency. This too is an insufficient condition to engender or maintain key pecking, as is particularly evident in the data of P85 and P2853 in Procedures II and IV. Furthermore, Brown and Jenkins (1968) did not obtain key pecking on a continuously illuminated key in the presence of which food was occasionally delivered. Nor did Gamzu and Williams (1971) observe key-pecking when food was random with respect to the illumination of the keys.

Thus, it appears that the necessary conditions under which a key stimulus will educe pecking in the naive pigeon are those in which the stimulus in question is differentially associated with a higher frequency of food presentations than obtains in the absence of that stimulus. This is clearly the case in this experiment and also in studies using a trials procedure (Gamzu, 1971).

Nonetheless, pecking did occur during the stimulus associated with the EXT and VT 100-sec components of Procedures I, II, and V. One possible contributing factor is stimulus generalization. Pecking during the intertrial interval in auto-shaping procedures did not occur if the key was dark, but did occur if the key was illuminated with a color different from the color during the trial (Brown and Jenkins 1968, Experiment 3). Moreover, the present data indicate that pecking at the stimulus associated with the lower frequency of food presentation developed only after the pigeon was already pecking during the stimulus associated with the higher frequency of food presentation. Another possibility is that this responding was maintained by changes in the key stimulus to the one correlated with the VT 33-sec component, which may occasionally have followed a key peck closely in time. The VT 33-sec stimulus may in turn have served as conditioned reinforcer, by virtue of its predictive value with respect to food (see Egger and Miller, 1962).

The effectiveness of a stimulus-food contingency in maintaining responding in the present experiment raises questions about the role of such contingencies in conventional operant procedures, in which food presenta-

tion is also response-dependent. It may be that in all procedures in which stimulus-reinforcer and response-reinforcer contingencies influence the same class of behavior (e.g., key pecking in pigeons) the two types of contingencies have a mutually enhancing effect. The phenomenon of positive behavioral contrast (e.g., Reynolds, 1961) provides empirical support for this proposition. When a procedure is shifted from *mult VI VI* to *mult VI EXT*, as the responding of pigeons in EXT decreases, responding in the VI increases. By the present account, the change from *mult VI VI* to *mult VI EXT* introduces a stimulus-reinforcer contingency. This new source of control over responding may well be responsible for the positive contrast elevation effect. Moreover, it may be that any experimental operation that results in different conditions of food delivery (not necessarily only frequency) in the presence of different stimuli may have similar effects on key pecking as long as food presentations are part of the procedure. Such operations would not necessarily generate key pecking in naive pigeons but might affect already established key pecking. Thus, for example, changes from *mult VI VI* to *mult VI VI + punishment* (Brethower and Reynolds, 1962) might produce contrast because the stimuli signal different conditions of reinforcement, rather than different frequencies of reinforcement. For similar reasons, *mult VI DRL* schedules might be expected to produce contrast (Terrace, 1968). This more general view, which proposes to account for these different contrast-producing procedures, implies that whenever a stimulus is unambiguously associated with some later event, it will exert control over the class of behavior that the later event directly influences. Thus, in the present experiment, that the key is a differential signal is responsible for its control over behavior, but that it is a differential signal for the presentation of food accounts for the class of behavior it comes to control—key pecking.

While the foregoing speculations are in need of experimental support, the clear and powerful control of pecking exerted by stimulus-reinforcer contingencies in the present experiment necessitates more careful analysis of operant procedures that entail stimulus-correlated reinforcement, even where the latter is not the focal point of the experimental

design. Moreover, such concerns are probably not limited to key pecking in the pigeon, for auto-shaping by means of stimulus-reinforcer pairings has been reported with bobwhite quail (Gardner, 1969), rhesus monkeys (Sidman and Fletcher, 1968), fish (Squier, 1969), rats, (Smith, Borgen, Davis, and Pace, 1971; Peterson, Ackil, Frommer, and Hearst, 1971) and squirrel monkeys (Gamzu, 1972).

REFERENCES

- Appel, J. B. and Hiss, R. H. The discrimination of contingent from non-contingent reinforcement. *Journal of Comparative and Physiological Psychology*, 1962, **55**, 37-39.
- Brethower, D. M. and Reynolds, G. S. A facilitative effect of punishment on unpunished behavior. *Journal of the Experimental Analysis of Behavior*, 1962, **5**, 191-199.
- Brown, P. and Jenkins, H. M. Auto-shaping of the pigeon's key peck. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 1-8.
- Edwards, D. D., West, J. R., and Jackson, V. The role of contingencies in the control of behavior. *Psychonomic Science*, 1968, **10**, 39-40.
- Egger, M. C. and Miller, N. E. Secondary reinforcement in rats as a function of information value and reliability of the stimulus. *Journal of Experimental Psychology*, 1962, **64**, 97-104.
- Gamzu, E. *Associative and instrumental factors underlying the performance of a complex skeletal response*. Unpublished doctoral dissertation, University of Pennsylvania, 1971.
- Gamzu, E. *Auto-shaping, and the failure of auto-maintenance in squirrel monkeys*. Paper presented at the Southeastern Psychological Association Meeting, Atlanta, Georgia, April, 1972.
- Gamzu, E. and Williams, D. R. Classical conditioning of a complex skeletal act. *Science*, 1971, **171**, 923-925.
- Gardner, W. M. Auto-shaping in bobwhite quail. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 279-281.
- Herrnstein, R. J. Superstition: a corollary of the principles of operant conditioning. In W. K. Honig (Ed.), *Operant behavior; areas of research and application*. New York: Appleton-Century-Crofts, 1966. Pp. 31-51.
- Herrnstein, R. J. and Morse, W. H. Some effect of response-independent positive reinforcement on maintained operant behavior. *Journal of Comparative and Physiological Psychology*, 1957, **50**, 461-467.
- Lachter, G. D. Some temporal parameters of non-contingent reinforcement. *Journal of the Experimental Analysis of Behavior*, 1971, **16**, 207-217.
- Lattal, K. A. and Mazey, G. C. Some effects of response-independent reinforcers in multiple schedules. *Journal of the Experimental Analysis of Behavior*, 1971, **16**, 225-231.
- Neuringer, A. J. Superstitious key pecking after three peck-produced reinforcements. *Journal of the Experimental Analysis of Behavior*, 1970, **13**, 127-134.

- Peterson, G. B., Ackil, J. E., Frommer, G. P., and Hearst, E. "Auto-shaping" in the rat using food and brain shock UCSs. Paper presented at the annual meeting of the Psychonomic Society, St. Louis, Missouri, November, 1971.
- Rescorla, R. A. and Skucy, J. C. Effect of response independent reinforcers during extinction. *Journal of Comparative and Physiological Psychology*, 1969, **67**, 381-389.
- Reynolds, G. S. Behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1961, **4**, 57-71.
- Sidman, M. and Fletcher, F. G. A demonstration of auto-shaping with monkeys. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 307-309.
- Skinner, B. F. *The behavior of organisms: an experimental analysis*. New York: Appleton-Century-Crofts, 1938.
- Smith, S. G., Borgen, L. A., Davis, W. M., and Pace, H. B. Automatic magazine and bar-press training in the rat. *Journal of the Experimental Analysis of Behavior*, 1971, **15**, 197-198.
- Squier, L. H. Auto-shaping key responses with fish. *Psychonomic Science*, 1969, **17**, 177-178.
- Staddon, J. E. R. and Simmelhag, V. L. The "Superstition" experiment: A reexamination of its implications for the principles of adaptive behavior. *Psychological Review*, 1971, **78**, 3-43.
- Terrace, H. S. Discrimination learning, the peak shift and behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 727-741.
- Zeiler, M. D. Fixed and variable schedules of response-independent reinforcement. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 405-414.

Received 15 December 1971.

(Final acceptance 28 July 1972.)